**International Journal of Technology and Human Interaction**
Volume 19 • Issue 1

# Assessment of the Building Situation Tool Adoption Among Firefighters

Filip Sever, Kajaani University of Applied Sciences, Finland*
https://orcid.org/0000-0001-7732-1994

## ABSTRACT

Technology is a standard tool that first responders use in their assessment and planning during disasters. Despite the considerable number of hardware and software solutions adopted, first responders still often rely on paper plans when examining indoor disasters. The purpose of this research is to investigate the technical competencies of firefighters and test the building situation tool (BUST) to replace the paper plans. A mixed method approach was used to assess the technology self-efficacy and gather insight into perceived usefulness, ease of use, and the user experience from the firefighters (N=20). The findings show a sufficient level of competency, and that first time users prefer guided instructions, clarity in the user interface, controls, and options to customize the user interface. The findings have practical implications for the future development of BUST and its adoption to the workflow of firefighters.

## KEYWORDS

Disaster Management, Indoor Disaster Management, Perceived Ease of Use, Perceived Usefulness, Technology Self-Efficacy, User Experience, Workplace Learning

## ASSESSMENT OF THE BUILDING SITUATION TOOL ADOPTION AMONG FIREFIGHTERS

Modern buildings in Finland are equipped with sensors that monitor and manage the comfort and safety of the people inside. Automated heating, ventilation, and air conditioning (HVAC) systems within the buildings optimize the use of resources for indoor space. Sensors throughout the building can monitor temperature, humidity, carbon dioxide levels, smoke, movement, and open or closed doors. This sensor data helps to maintain building temperatures, circulate air, and automatically lock or unlock doors based on preset values and occupancy requirements of the space. The system also monitors for fires, alerting authorities if a fire is detected.

Although buildings are equipped with an array of sensors, first responders continue to rely on paper versions of a building's plans during emergencies (Rescue Act, 2011). These plans are located inside the building. Having access to sensor data allows firefighters to plan their work as they depart to the disaster site.

DOI: 10.4018/IJTHI.317749

*Corresponding Author

To ensure efficiency, first responders (firefighters in the current study) must accept new technologies, be confident in their skills, have support from their workplace, and designate time for learning. The technology acceptance model (TAM) is the most notable method to predict technology acceptance (Davis, 1989). Research with TAM focuses on measuring the user's intention to use technology through constructs like perceived usefulness (PU) and perceived ease of use (PEOU). Its factors measure external variables that influence the intention to use (Venkatesh & Davis, 2000; Venkatesh et al., 2003). Recent research on the technology acceptance of firefighters has modified TAM variables to suit the context of the current study.

Weidinger et al. (2021) examined German firefighters' acceptance of the emergency response information system (ERIS) platform, which gathers, analyzes, and shares information to provide a real-time situational overview of responding units. The study focused on adapting TAM to assess the acceptance of participating firefighters and create a benchmark of ERIS (Weidinger et al., 2021). The model was based on TAM and its extensions, most notably the accuracy, format, and currency of the information provided by ERIS. Although the proposed model suits the current study, it presents similar limitations, including a limited number of potential participants and a homogenous group.

A second study, which focuses on Spanish firefighters, examined the relationship between age, grades, and TAM scores in the context of technology-supported learning (Lluch & Gros, 2018). The findings show no relationship between the variables of age, grades, and TAM scores. The study did, however, find a positive relationship between intention to use, PU, voluntariness, and obtained grades.

Figure 1 shows the Building Situation tool (BUST), developed to trial the use of sensors for the work of firefighters. BUST gathers data from building sensors and presents the status of each room in real time. Yellow or red notifications appear when sensor values rise above a predetermined room temperature value. Yellow notifications represent above-normal values. Red notifications represent extreme values. In addition, the user can toggle through emergency resources inside the building, such as evacuation routes and the location of firefighting equipment or infrastructures.

The authors postulate that the concepts proposed by Haskins et al. (2020) (i.e., teaching general concepts, learning, planned training tasks, suitable trainer capabilities, and the research element) are of significance when enabling learning through other technologies. The firefighters' learning

**Figure 1. BUST user interface**

environment requires an immersive experience and learning goals aimed at acquiring knowledge and skills applicable to the practiced scenario. Thus, the authors consider the context of the technology application when planning BUST testing with end users. In addition to evaluating BUST, the authors examine the firefighters' technological self-efficacy to gain insight into their perceived ability to achieve goals using technology and their experience using BUST.

## THEORETICAL BACKGROUND

### TAM

TAM, a three-stage process, provides insight into how individuals come to accept and use technologies (Davis, 1986). The model includes factors that examine PU and PEOU. PU examines the degree to which technology is useful to the applied context. As part of this study, PU is applied to the relationship between first responders' tasks during emergencies and the ability of the tool to meet the requirements of the actions. PEOU describes the degree of effort required to use the tool. Elements like interactivity, interface design, and navigation influence the user's attitude toward the PEOU of the tool. The attitude toward using the tool is modeled based on the findings from PU and PEOU. External factors (design features of a technology) trigger cognitive responses within the user (PEOU and PU), leading to the formation of affective responses (attitude toward using the technology) that influence behavior (Davis, 1989, 1993; Marikyan & Papagiannidis, 2021).

The expanded model, TAM2, includes additional factors that capture social influence, cognitive instrumental processes, and experience (Venkatesh & Davis, 2000). Up to 60% of user acceptance can be explained through TAM2. Given the specific use case of the tool, TAM2 provides further insight into an individual's perception of usefulness influenced by external variables. These include the subjective norm (experience and voluntariness), image, job relevance, output quality, and result demonstrability.

The unified theory of acceptance and use of technology (UTAUT) model was formulated to gather fragmented research and theory on the acceptance of information technology (Venkatesh et al., 2003). UTAUT confirms significant support for three determinants of intention to use (performance expectancy, effort expectancy, and social influence) and two direct determinants of usage behavior (intention and facilitating conditions). The study highlighted that effort expectancy on intention to use is influenced by gender and age for women and older workers; however, these influences decrease with experience. In addition, social influence is a significant factor in older workers, particularly women. This isin the early stages of adoption (Venkatesh et al., 2003).

UTAUT is extensively used in technology acceptance and use. Still, researchers tend to extend the model with suitable constructs for their studies. Chao (2019) extended the UTAUT model with the constructs of mobile self-efficacy, perceived enjoyment, satisfaction, trust, and perceived risk for assessing mobile learning in university students. The study confirmed the significant positive effects of performance expectancy and effort expectancy on behavioral intentions. Given the many TAM models and constructs for predicting the intention to use technology, researchers will adapt the suitable model depending on their needs.

Technologies continue to advance, becoming more widely available and affordable. In turn, stakeholders are considering their potential for prevention and safety work. The demand for security technologies has expanded from economic sectors, such as the automotive industry and banking, into the public sector and government institutions.

Civil security policy, research, development, and adoption of methodologies and technology are part of the European Union agenda (Bierwisch et al., 2015; European Commission, 2021). Technology acceptance research is used to examine both software and hardware solutions for civil security (Allen, 2019; Weidinger et al., 2021). Technologies are assessed to provide training for specific scenarios or support aspects of the emergency services work. Training solutions must be a realistic replication of fieldwork to correspond to potential scenarios and situations. Tools must be dependable and easy to use to facilitate adoption. They must also meet communication needs and have user-centered design principles (Haskins et al., 2020).

## Self-Efficacy

Self-efficacy is a person's belief in their ability to achieve a set of tasks or goals (Bandura, 1978). The constructs of self-efficacy and its beliefs are related to clinical problems like phobias, addiction, depression, social skills, assertiveness, stress, smoking, pain control, health, and athletic performance (Pajares, 1997), anxiety disorders (Schønning & Nordgreen, 2021), job satisfaction (Kasalak & Dağyar, 2020), job performance (Mi-Young et al., 2019), and stress response (Schönfeld et al., 2017). The construct has a range of applications in examining the domains of human behavior.

Self-efficacy beliefs affect a person's motivation, learning, self-regulation, and achievement outcomes (Schunk & Dibenedetto, 2016). In the professional environment, self-efficacy influences work-based performance. The influence of self-efficacy is greater than goal setting, feedback, or organizational behavior interventions (Stajkovic & Luthans, 1998).

In the context of learning, self-efficacy describes the learner's confidence in their ability to achieve an educational goal (Schunk & Dibenedetto, 2016). As learners progress through their schooling, competence beliefs decline. Poor preparation, ability groupings, or social comparison can weaken self-efficacy beliefs (Schunk & Dibenedetto, 2016). Employees with higher self-efficacy beliefs work harder to learn how to perform tasks. They are more confident in their success (Lunenburg, 2011). When introduced to technologies, persons with lower self-efficacy may exert less effort to learn and succeed in the use of the technology. When a person is learning to use technology, perceived similarities and differences from prior experience influence learning in the new context (Marton, 2009). As such, accepting common design elements and interactive methods is important in the adoption of technologies.

The technology self-efficacy construct describes a person's belief in their ability to successfully perform a technologically sophisticated new task. As such, the construct describes a person's confidence in successfully using a specific technology rather than general competencies described by computer self-efficacy. The constructs of technology self-efficacy and computer self-efficacy may be similar; however, only technology self-efficacy influences PEOU (Holden & Rada, 2011). Outcomes and findings from variables may vary depending on the population sample and technology used in the research.

Research has verified a significant positive influence of technology self-efficacy on technology acceptance and utilization (Pan, 2020). Attitude toward technology has a significant positive influence on technology self-efficacy, which is explained at a ratio of 41% (Celik & Yesilyurt, 2013). Many students enter college or the workforce without basic computer knowledge or skills. This directly affects their technology self-efficacy, causing higher levels of anxiety when using technology (Huffman et al., 2013). Technology self-efficacy of users increases with the use of technology. Time, training, vicarious experiences, positive attitude, and organizational support are required to facilitate the learning and growth of the user's self-efficacy beliefs (Kent & Giles, 2017).

## Learning and Performance in the Workplace

Firefighters use established procedures and technology within their work. Periodic exercises are held to practice emergency scenarios. The training includes all levels of the command chain. When evaluating new tools and technologies for procedures, personnel require training in the tool. This training allows end users to familiarize themselves with the tool's capabilities, as well as how it can be used within the framework of the procedure. Learning and evaluation occur at the same time when end users are part of the design process of the technology. Both the developers and end users benefit from the process, which improves the alignment between requirements and product development (Thalmann et al., 2018).

Workplace environments and tasks differ between jobs; however, there are similarities between the factors that influence learning. Both informal and formal learning occurs within the workplace. Informal learning may be implicit, reactive, or deliberate (Eraut, 2004). Implicit learning refers to unconscious learning (without the learner's awareness) of new knowledge or skills. Reactive learning requires consciousness and effort, with little time to think. Deliberate learning is an opportunity to acquire new knowledge through learning with a goal. Formal learning, on the other hand, are organized training and learning activities that generate explicit, formal knowledge and skills (Tynjälä, 2008). The presence of one learning method does not imply the absence of the other. Workplace learning benefits both the individual (i.e., creating knowledge, skills, and competencies) and the organization via an increase in output or value created by individuals (Manuti et al., 2015).

Two schools of thought exist in the context of workplace learning and measuring performance toward achieving goals. The first, assessment of task performance, looks at the outcome of a particular behavior toward achieving a goal (Motowidlo & Kell, 2013). The second is the behavior itself (Campbell, 1990). Performance is, therefore, measured through the outcomes of the task or the behaviors exhibited during the task. Measuring work performance based on outcomes carries limitations because it does not include the dimensions of work behaviors within work performance (Abun et al., 2021). Simulations, work sampling, and proxies can be used to observe work-specific tasks and evaluate performance. These methods allow the assessment of employees and their capabilities in circumstances that would be otherwise difficult to assess (Campbell & Wiernik, 2015).

The TAM model and its external variables have a positive influence on subjective norms, computer self-efficacy, and facilitating conditions (Scherer et al., 2019). The variables of subjective norms and facilitating conditions shape the user's perception of their work environment and the system in place, influencing their behavior and workplace learning (Eraut, 2004; Guerin & Toland, 2020).

### Aim and Research Questions

BUST was developed in cooperation with a fire officer. It, however, lacks thorough testing and evaluation on a greater scale. The aim of this study is to examine the current state of BUST and collect feedback for future development:

**RQ1:** What is the technology self-efficacy, PEOU of BUST, and PU of BUST among firefighters?
**RQ2:** How do users experience BUST?

## METHOD

### Context and Participants

The BUST system was designed to replace paper versions of building plans and provide firefighters with an enhanced situational overview of the disaster scene. During its development, firefighters required that the tool be intuitive and easy to learn. They did not want the tool's use to require advanced computer skills. The firefighters wanted the learning and use of BUST to be like other tools used in mission management and field operations. Options to visualize points of interest in the building, recognize sensor types, read sensor information, examine timestamps, and plot routes needed to be clear and concise. Touch functionalities should mirror smartphones (pinch to zoom, double-tap confirmation, and two-finger interaction to manipulate 3D models or hold and drag objects).

Firefighters' acceptance of BUST required the technology's availability for testing. In addition, their workplace needed to support its learning through both formal and informal methods. Significant constructs influencing the workplace learning process include user's self-efficacy beliefs, the learning environment in which learning takes place, and the context of learning (Lunenburg, 2011; Tynjälä, 2008). A fire officer was consulted throughout the development process to facilitate learning, self-efficacy beliefs, and adoption. Study participants were introduced to BUST in one-on-one sessions. Workplace learning factors were considered for the learner and the learning context. The learner required a challenge, value, feedback, support, confidence, and commitment. The context of the learning requires structure, measures of performance and progress, and support from the working environment (Eraut, 2004).

The mixed method study approach was used to collect, analyze, and report qualitative and quantitative findings of the study. Table 1 shows the chronological order of the process. Quantitative responses provide insight into perceived technology self-efficacy and TAM constructs; qualitative findings offer guidance on improvements to BUST (Story & Tait, 2019). Activities reference the corresponding research question.

Respondents participated in the study one at a time. The researcher introduced the purpose of the study and BUST. Questionnaires and tasks were provided in a Microsoft Forms file. The study was split into the following three phases: (1) prior to use of BUST; (2) use of BUST; and (3) after use of BUST. The data was gathered in phase 1 and phase 3. During phase 2, participants were introduced to BUST and completed a series of tasks. The task design followed the current procedure for fire emergencies in buildings. The constructs of self-efficacy, PEOU, and PU used seven-point Likert scales. The open-ended user experience questionnaire (see Appendix) and unstructured interviews were part of the qualitative study design aimed at prompting analysis and evaluation of the participants' use of BUST (Tofade et al., 2013). It allowed space to express personal experiences and beliefs (Story & Tait, 2019).

The study participants (n = 20) were Finnish firefighters and fire officers. The study was conducted in the Finnish language. All contacted respondents agreed to complete the study. Table 2 shows the demographic data of the participants. Most of the participants were male (95%). They were between the age of 25 and 44 (70%) and had more than 11 years of experience (60%). The number of participants without a university degree was higher (65%) than the number of participants with a completed degree (35%).

Holden and Rada (2011) adjusted the original TAM model for their study to account for the usability construct. The adjustment was made to account for the requirements of the users with the technology (rather than PEOU in the standard form). The study found that the adjusted PEOU and

**Table 1. Research outline**

<table>
<tr><th></th><th>Activity</th><th>Method</th><th>Construct</th></tr>
<tr><td rowspan="2">Phase 1</td><td>Introduction of the study, collection of demographic data</td><td>Single-choice questions</td><td>Demographic data</td></tr>
<tr><td>Questionnaire on perceived technology self-efficacy (RQ1)</td><td>Seven-point Likert scale</td><td>Perceived technology self-efficacy</td></tr>
<tr><td>Phase 2</td><td colspan="3">1. Introduction of BUST to Participant: Guided overview of the program and its functions<br>2. Participant Completes Series of Tasks Using BUST: Framing the use of the program in the context of participant's work</td></tr>
<tr><td rowspan="4">Phase 3</td><td>Completion of a questionnaire on user experience (RQ2)</td><td>Open-ended questions</td><td>User experience</td></tr>
<tr><td>Questionnaire on perceived ease of use of BUST (RQ1)</td><td>Seven-point Likert scale</td><td>TAM, Perceived ease of use</td></tr>
<tr><td>Questionnaire on perceived usefulness of BUST (RQ1)</td><td>Seven-point Likert scale</td><td>TAM, Perceived usefulness</td></tr>
<tr><td>Interviews with four participants to supplement the user experience questionnaire (RQ2)</td><td>Unstructured interviews</td><td>User experience</td></tr>
</table>

**Table 2. Demographic data of participants**

| Characteristic | | n | % |
|---|---|---|---|
| Gender | Male | 19 | 95 |
| | Female | 1 | 5 |
| Age | 18-24 | 1 | 5 |
| | 25-34 | 6 | 30 |
| | 35-44 | 8 | 40 |
| | 45-54 | 4 | 20 |
| | 55-64 | 1 | 5 |
| | 65+ | 0 | 0 |
| Years of experience | 0 – 2 | 3 | 15 |
| | 3 – 5 | 2 | 10 |
| | 6 – 10 | 3 | 15 |
| | 11 – 20 | 6 | 30 |
| | 21+ | 6 | 30 |
| Education | Vocational school | 10 | 50 |
| | University, not completed | 3 | 15 |
| | Bachelor's degree | 4 | 20 |
| | Master's degree | 3 | 15 |
| | PhD | 0 | 0 |

usability constructs were population independent and generalizable. Holden and Rada's (2011) construct was used for the current study due to the small sample size.

## Data Analysis

The quantitative data analysis utilized existing TAM and self-efficacy instruments used in testing first responder technology acceptance (Allen, 2019) and technology self-efficacy (Holden & Rada, 2011). The three survey sections were built in Microsoft Forms. Survey responses were stored in a spreadsheet. The data was exported to SPSS for analysis following the completion of the questionnaire. Then, the three constructs were analysed with descriptive statistics.

Table 3 shows the results summary of the descriptive statistics, mean, standard deviation, and reliability test. Due to the limited number of participants, the constructs were used as independent variables that considered self-efficacy, ease of use, and usefulness. A similar study by Nakamura et al. (2019), however, highlighted the significance of utilizing both a qualitative and quantitative

**Table 3. Ranges, means and standard deviation, and reliability of constructs**

| Construct | Minimum | Maximum | M | SD | α |
|---|---|---|---|---|---|
| Technology self-efficacy | 1 | 7 | 4.66 | 1.79 | .965 |
| Ease of use | 1 | 7 | 5.48 | 2.07 | .851 |
| Usefulness | 1 | 7 | 4.70 | 1.77 | .946 |

approach in technology evaluation. The TAM questionnaire informs only on PEOU and usability. The addition of open-ended questions provides space for participants to elaborate on their experience.

The qualitative content analysis allowed researchers to examine how users experience the BUST tool. In addition, they could identify the themes that emerged from the collected open-ended questionnaires (Annex 1) and interviews. There is limited research on the use of TAM in the civil security domain. However, studies have used mixed methods to assess the practical potential of tools and identify factors that contribute to the acceptance or decline of adoption (Weidinger et al., 2021).

After the interview recordings were transcribed for reading, they were imported into NVivo for automatic coding. The interview data was read multiple times to examine meaningful sentiments and categories. Table 4 shows the coding scheme used in the analysis. Using NVivo, texts were analyzed with automatic coding, sentiment coding, and word frequency analysis. The following primary categories were formed through NVivo and reading: *use, menu, icons, interface layout, visibility, intuitiveness, introduction, instructions, training, learning,* and *interaction*.

Higher categories were chosen depending on the element of BUST they are concerned with and the type of sentiment (whether positive or negative). The positive sentiment category was merged into *user experience, user interface, training,* and *introduction with instructions*. The negative sentiment category was merged into *user interface, movement controls*, and *highlighting of critical information*. The chosen categories represented factors that contribute to positive or negative sentiments in experiencing BUST. Secondary coding was not performed in this study. Figures 2, 3, and 4 contain participants' responses on the construct of perceived technological self-efficacy, PU, and PEOU. For descriptive purposes, the seven-point Likert scale was merged into *disagree*, *neutral*, and *agree.*

## FINDINGS

### RQ1: What is the Technology Self-Efficacy of Firefighters, PEOU of BUST, and PU of BUST Among the Firefighters?

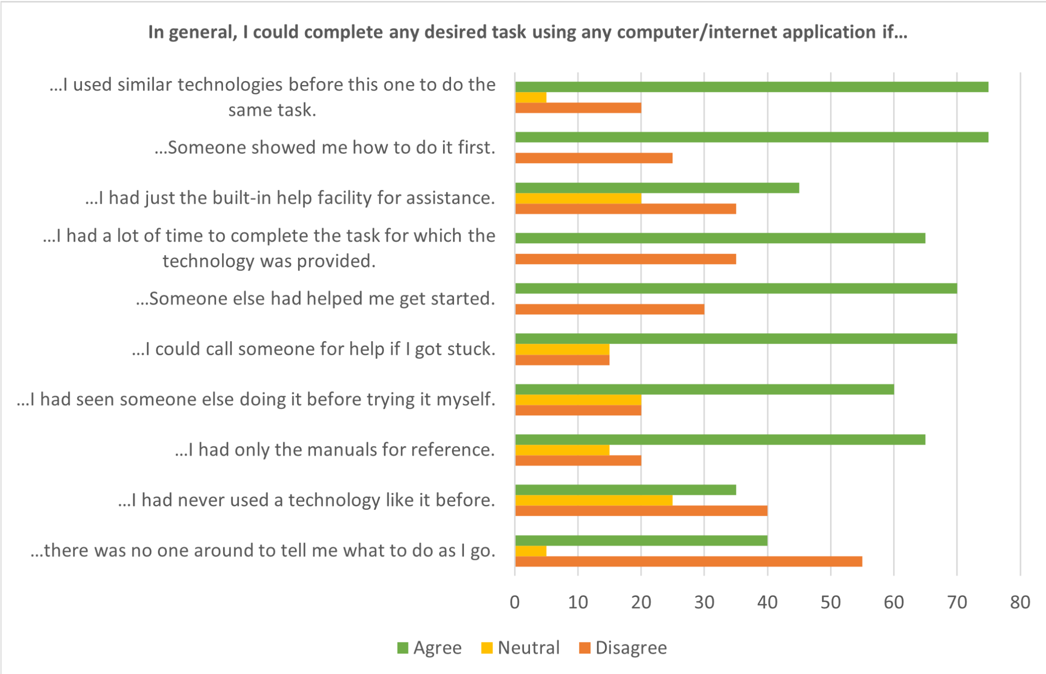
#### *Technology Self-Efficacy of Firefighters*

Regarding perceived technology-efficacy, most respondents stated they could not complete any task without someone to tell them what to do (55%). Most (40%) were unable to complete the task if they had not already used the application (see Figure 2). Most could complete the task if they had a reference manual (65%), saw someone else complete the task before they used it (60%), were able to call someone if they get stuck (70%), had someone help them get started (70%), or had a lot of time (65%). A relative majority could complete the task with built-in help (45%). Most could complete

**Table 4. Coding scheme**

| Code | Coding rule | Example |
|---|---|---|
| User experience | Mentioning the use of BUST, interaction with functionalities, and intuitiveness. Mentions of feelings toward the experience. | "It took some time to get to grips with the basic use of the software, menus, and so on, but the basic view was informative.'' |
| Training | Mention of training as a requirement to improve skills with the technology. | "Using the software efficiently would require more practical training.'' |
| User interface | Mentioning various visual elements on the screen, including icons, buttons, colors, and animations. | "Well-functioning user interface. I would hope for clearer icons and menus." |
| Introduction | Mention of the initial introduction of the tool by the researcher, including an explanation of the components and functionalities. | "I am sure it would have been challenging to get started without the preliminary instructions.'' |

**Figure 2. Responses for perceived technology self-efficacy**




the task if someone showed them how to do it first (75%) or had used similar technologies in the past (75%).

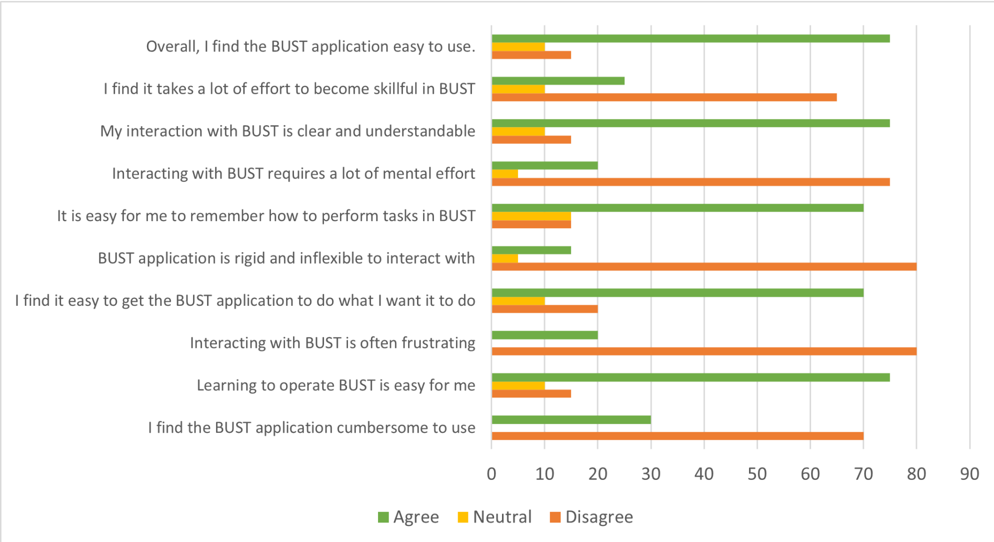
The findings show a positive level of self-efficacy reported by participants. The lowest confidence was found in the following response: "… I had never used a technology like it before." However, all participants completed the given tasks. Furthermore, participants had not interacted with BUST prior to the testing. They were only shown how to use the technology. Two of the questions/responses were similar. The first was: "… Someone else helped me get started." The second was: "… Someone showed me how to do it first." the difference was the users' perception of internal control (Venkatesh & Davis, 2000). The response, "… Someone showed me how to do it first,'' implies that a person was present throughout the learning experience. The response, "… Someone else had helped me get started," refers to a brief introduction to the system.

### *PEOU of BUST*

As shown in Figure 3, most respondents did not feel that BUST was cumbersome to use (70%), interaction was frustrating (80%), interacting with the application was rigid and inflexible (80%), or it took significant effort to become skillful in its use (65%). Most respondents agreed that it was easy to learn how to operate BUST (75%), it was easy to get BUST to do what they wanted (70%), and it was easy to remember how to perform tasks in BUST (70%). They also agreed that interacting with BUST was clear and understandable (75%) and it was easy to use (75%).

Responses were collected after the testing and completion of assigned tasks. The findings reflect that BUST was easy to use. There were no significant outliers from the collected responses. The lowest score observed was the following: "I find it takes a lot of effort to become skillful in BUST." Given the limited time for demonstration and use by participants, the assessment highlights the need for longer interactions. Therefore, it should focus on informal approaches to assessment and learning. Given

**Figure 3. Responses for perceived ease of use for BUST**

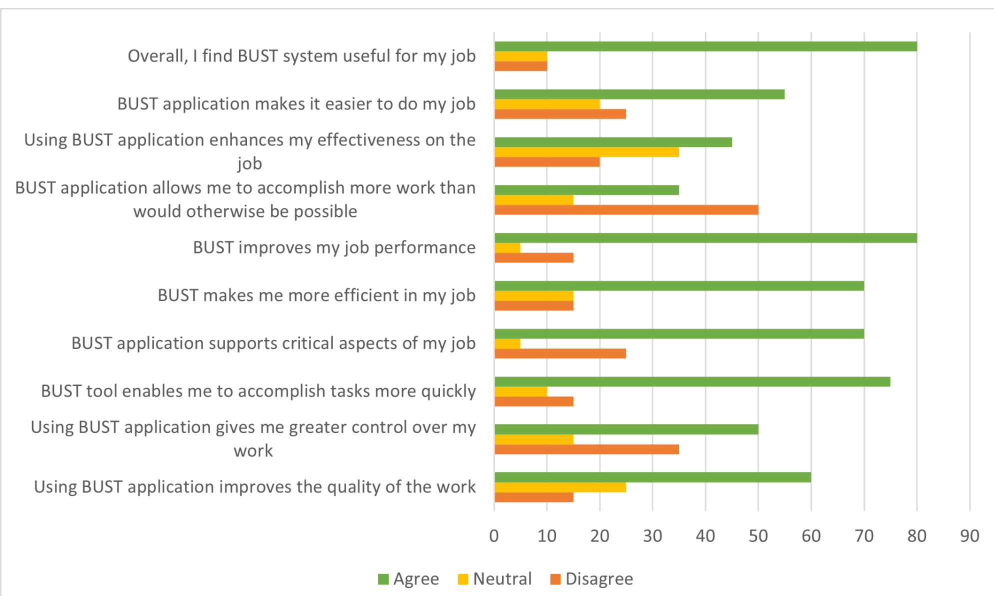



the highest standard deviation values, further emphasis is required on the ease of use and usability aspects of the technology. Similar findings are reflected in the qualitative sections of the findings.

### *PU of BUST*

According to Figure 4 most respondents felt that BUST improved the quality of their work. Half (50%) agreed that BUST gave them better control over their work. Most said that BUST enabled them to accomplish their tasks more quickly (75%), supported critical aspects of their job (70%), made

**Figure 4. Responses for perceived usefulness of BUST**



their job more efficient (70%), and improved their job performance (80%). However, most (50%) did not find that BUST helped them accomplish more work. The relative majority (45%) agreed that it enhanced their effectiveness on the job. Most agreed that BUST made their job easier (55%) and was useful for their job (80%).

Responses to the usefulness construct highlight areas that required additional work. The lowest scores were recorded in the following constructs: "using the BUST application gives me greater control over my work" and "the BUST application allows me to accomplish more work than would otherwise be possible." The findings indicate that additional work is required in the teaching of the use of the tool, clarity in functionality, and improvement in user experience.

Studies that examine technologies in the context of learning (Nakamura et al., 2019; Park, 2009) and police officers (Allen, 2019) reported similar scores related to PU and PEOU (see Table 5). Most findings were within a one-point range on the seven-point Likert scale. The lower score on the usefulness of BUST is a reflection on the limited features and functionalities in the early development stage. The following sections provide respondents' feedback and guidance on development.

## RQ2: How Do Users Experience BUST?

Respondents noted that the tool was easier to understand if they were given an introduction. Respondents were guided through the navigation of the menus and functionalities before receiving a set of tasks to complete. The technological self-efficacy questionnaire and user experience questionnaire highlighted the significance of having a person teach the user or having a person available to ask for help. Studies on informal workplace learning support the significance of peer interaction and autonomy as main sources for learning. The most common strategies include model learning, vicarious feedback, and application of one's own ideas (Amenduni et al., 2022).

Respondents discussed the implications that such a tool has on an incident and its related procedures. First responders rely on paper plans at the incident site. Therefore, the control room at the fire station does not have information on the site (other than descriptive reports). In such cases, if no executive fire officer is on site, the unit leader takes command because they are the person with the most knowledge. The firefighters feel that BUST is a solution to close the gap in information.

A lack of information was addressed throughout the development process as firefighters tested BUST and interacted with developers. During development, attention was given to the co-creation process. As firefighters learned about BUST, they were able to compare it with other technologies and tools (Hajian, 2019). A transfer of learning occurs when the purpose of the technology matches the use context of the tool. Learners can infer knowledge that needs to be adapted for the required context (Rivière et al., 2019). Furthermore, as participants complete tasks, their self-efficacy increased, leading to enhanced motivation, learning, self-regulation, and achievement (Schunk & Dibenedetto, 2016).

During the use of BUST, respondents highlighted the intuitive nature of the tools, features, and menu navigations. Participants mentioned that experience with similar programs, applications, or video games was a contributing factor in their ability to learn and use the platform. After the completion of the tasks, responders noted that the tools were easy to use. However, they requested further training to better learn the tool. The importance of thorough training in tools (in the lab and in training exercises) was mentioned. Participants found the user interface easy to navigate and logical. However, the icons needed to be kept up to date and larger in size. Users felt that the icons and symbols should mirror official documentation. Lastly, the tool did not require a 3D view.

**Table 5. Mean values compared with findings of other studies**

| Construct | BUST scores | Nakamura et al. (2019) | Allen (2019) | Park (2009) |
|---|---|---|---|---|
| Perceived usefulness | 4.70 | 5.18 | 5.56 | 4.25 |
| Perceived ease of use | 5.48 | 5.44 | 5.58 | 5.54 |

Participants' negative sentiments mentioned the scale of the user interface and clarity of the menus and icons. In the current version of BUST, the expanded toolbars and menus occupied a significant portion of the screen space. Having all menus open resulted in poor visibility of the disaster site. Icons of the building model did not scale when zooming in or out, which resulted in poor readability when zooming too close or too far from the building. Thus, participants suggested that the program include options to adjust the scale of menus and icons. Camera movement was set to the W, A, S, and D keyboard keys, which users found confusing because they expected to use the arrow keys for that function. The choice to use letters for camera movement was made during development because it allowed for the simultaneous use of functions through the space bar, shift key, and control (Ctrl) key. In addition, users mentioned that risk objects and areas were not clearly highlighted; therefore, they suggested applying lower color transparency and higher visibility colors. The identified shortcomings of usability and user experience match the quantitative findings of PEOU, highlighting the need for improvements.

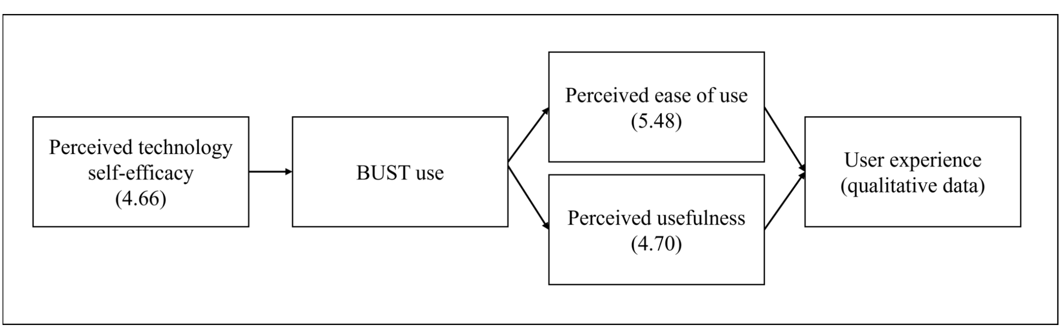
Figure 5 presents the research model of the study and overall results. The mean scores highlight the current evaluation of BUST. The qualitative user experience data provides context and recommendations for development.

## DISCUSSION

The purpose of this study was to examine BUST and the user experience of firefighters. The authors used both qualitative and quantitative methods to examine reasons beyond the potential adoption of BUST. Utilizing both methods gave an in-depth examination of the phenomena (Jaber, 2016; Vogelsang et al., 2013). The quantitative findings show that respondents are sufficiently competent in technology use and found BUST easy to use and valuable to their work. The results of this study align with prior research (Allen, 2019; Young Hwang et al., 2009), reflecting the positive attitude of participants toward technology and the acceptance of technology as a suitable tool for their tasks. The TAM model has been extensively used to predict user behavior, including in the areas of marketing, advertising, e-commerce, mobile banking, virtual reality, and e-learning (Marikyan & Papagiannidis, 2021). However, the TAM model remains case specific. Each study adapts TAM for the suitability of its own testing (Allen, 2019; Weidinger et al., 2021).

The qualitative findings reveal that, while users are competent in technology use, the initial demonstration of the tool is valued and contributes to the learning and consequent use experience. Furthermore, personalization of the BUST user interface and on-screen elements can be improved through customizability, allowing users to manipulate the size, colors, and transparency of items. This will add to their agency, sense of control, and cognition (Sundar & Marathe, 2010). The experience and technology should serve to deliver easy and efficient use as it achieves the learning objectives (Quintana et al., 2020).

**Figure 5. Research model**



These findings are in line with prior research that highlights the significance of perceived support and its influence on learning motivation (Lai et al., 2016; Pan, 2020). Learning motivation is found to influence self-efficacy beliefs and technology acceptance. This, in turn, impacts the learners' attitude toward using technology as a means of learning (Edmunds et al., 2012; Pan, 2020). In addition, to facilitate learning and performance, users require organizational support, challenge in their work, and confidence to learn and perform (Eraut, 2014).

## CONCLUSION

Information collected from building sensors has the potential to enhance the situational awareness of first responders, improving their work and safety during emergencies. This article evaluates the firefighters' competence, user experience, and acceptance when using BUST, a program that collects and presents sensor data. The constructs of perceived self-efficacy, PEOU, and PU show that participants possess sufficient technological competencies and are accepting of BUST as a tool for their work. Although efficacy is a significant determinant in the intention to use technology, findings suggest the need for instructions and the availability of learning support. These findings highlight the value of perceived support and its influence on learning motivation. Learning motivation is found to influence self-efficacy beliefs, technology acceptance. In turn, it impacts learners' attitude toward using technology as a means of learning. The results revealed that further development is required to improve the usefulness of BUST. Namely, it should allow for the customization and personalization of the user interface, customization of controls with keyboard and mouse, and the option to observe the building in 2D from a top-down view.

One limitation is that this study focused on the adoption of technology by all firefighters, regardless of rank. It benefits all operatives (for gathering information and gaining situational awareness) when departing to the disaster site. However, in the field, the unit leader primarily works with situational awareness tools. A second limitation is that the research was conducted primarily with firefighters from the Kainuu region in Finland. Therefore, the number of survey participants was limited and homogenous. Future research should gather samples on a national level. A larger sample size will allow for the inclusion of TAM as a complete model and provide a representative sample of the country. A third limitation is that the study did not consider the firefighters' perceived risk of adopting BUST. Perceived risk has been shown to affect technology adoption negatively and significantly, particularly in users who lack knowledge about the technology (Jayashankar et al., 2018; Wang et al., 2018).

Future research should focus on fire officers exclusively. Once in the field, fire officers are the primary users of technology tools in Kainuu. Future research should consider differences in procedure across the regions as a factor in assessing the adoption and use of tools. Furthermore, the ethnographic research approach should be considered when participants interact with the software. Studies should observe how users interact with the tool and use the think-aloud method to gather data on decision making and process tracing.

## ACKNOWLEDGMENT

The authors of this publication declare there is no conflict of interest.

## FUNDING AGENCY

This research was supported by the European Commission-funded program FASTER, under H2020 Grant Agreement 833507.

## REFERENCES

Abun, D., Nicolas, M., Apollo, E., Magallanes, T., & Nicolas, M. T. (2021). Employees' self-efficacy and work performance of employees as mediated by work environment. International. *Journal of Research in Business and Social Science*, *10*. doi:10.20525/ijrbs.v10i7.1470ï

Allen, M. (2019). Examining the technology acceptance of the iCOP application among police officers. *The Journal of Technology Studies*.

Amenduni, F., Ryymin, E., Katja, M., & Cattaneo, A. (2022). Facing disruptive changes with informal workplace learning strategies: The Experience of European Companies. *Frontiers in Psychology*, *13*, 889850. doi:10.3389/fpsyg.2022.889850 PMID:35693506

Bandura, A. (1978). Self-efficacy: Toward a unifying theory of behavioral change. *Advances in Behaviour Research and Therapy*, *1*(4), 139–161. doi:10.1016/0146-6402(78)90002-4

Bierwisch, A., Kayser, V., & Shala, E. (2015). Emerging technologies in civil security: A scenario-based analysis. *Technological Forecasting and Social Change*, *1010*, 226–237. doi:10.1016/j.techfore.2015.06.014

Campbell, J. P. (1990). Modeling the performance prediction problem in industrial and organizational psychology. In M. D. Dunnette & L. M. Hough (Eds.), *Handbook of industrial and organizational psychology* (pp. 687–732). Consulting Psychologists Press.

Campbell, J. P., & Wiernik, B. M. (2015). The modeling and assessment of work performance. *Annual Review of Organizational Psychology and Organizational Behavior*, *2*(1), 47–74. doi:10.1146/annurev-orgpsych-032414-111427

Celik, V., & Yesilyurt, E. (2013). Attitudes to technology, perceived computer self-efficacy and computer anxiety as predictors of computer supported education. *Computers & Education*, *60*(1), 148–158. doi:10.1016/j.compedu.2012.06.008

Chao, C.-M. (2019). Factors determining the behavioral intention to use mobile learning: An application and extension of the UTAUT model. *Frontiers in Psychology*, *10*, 1652. doi:10.3389/fpsyg.2019.01652 PMID:31379679

Davis, F. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *Management Information Systems Quarterly*, *13*(3), 319–340. doi:10.2307/249008

Davis, F. (1993). User acceptance of information technology: System characteristics, user perceptions and behavioural impacts. *International Journal of Man-Machine Studies*, *38*(3), 475–487. doi:10.1006/imms.1993.1022

Davis, F. D. (1986). *A technology acceptance model for empirically testing new end-user information systems: theory and results*. MIT. https://dspace.mit.edu/handle/1721.1/15192

Edmunds, R., Thorpe, M., & Conole, G. (2012). Student attitudes towards and use of ICT in course study, work, and social activity: A technology acceptance model approach journal item. *British Journal of Educational Technology*, *43*(1), 71–84. doi:10.1111/j.1467-8535.2010.01142.x

Eraut, M. (2004). Informal learning in the workplace. *Studies in Continuing Education*, *26*(2), 247–273. doi:10.1080/158037042000225245

Eraut, M. (2014). Professional learning and development in schools and higher education: International practice and policy. In O. McNamara, M. Jones, & J. Murray (Eds.), *Workplace learning in teacher education* (Vol. 10). Springer. https://www.springer.com/series/7908

European Commission. (2021). *Commission staff working document: Enhancing security through research and innovation* ((SWD) 422 final). https://home-affairs.ec.europa.eu/system/files/2021-12/SWD-2021-422_en.PDF

Guerin, R. J., & Toland, M. D. (2020). An application of a modified theory of planned behavior model to investigate adolescents' job safety knowledge, norms, attitude and intention to enact workplace safety and health skills HHS Public Access. *Journal of Safety Research*, *72*, 189–198. doi:10.1016/j.jsr.2019.12.002 PMID:32199561

Hajian, S. (2019). Transfer of learning and teaching: A review of transfer theories and effective instructional practices. *IAFOR Journal of Education*, *7*(1). doi:10.22492/ije.7.1.06

Haskins, J., Zhu, B., Gainer, S., Huse, W., Eadara, S., Boyd, B., Laird, C., Farantatos, J. J., & Jerald, J. (2020). Exploring VR training for first responders. *IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), 57-62*. IEEE. doi:10.1109/VRW50115.2020.00015

Holden, H., & Rada, R. (2011). Understanding the influence of perceived usability and technology self-efficacy on teachers. *Journal of Research on Technology in Education*, *43*(4), 343–367. doi:10.1080/15391523.2011.10782576

Huffman, A. H., Whetten, J., & Huffman, W. H. (2013). Using technology in higher education: The influence of gender roles on technology self-efficacy. *Computers in Human Behavior*, *29*(4), 1779–1786. doi:10.1016/j.chb.2013.02.012

Jaber, O. A. (2016). *An examination of variables influencing the acceptance and usage of e-learning systems in Jordanian higher education institutions* [Doctoral dissertation, Cardiff Metropolitan University]. https://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.690954

Jayashankar, P., Nilakanta, S., Johnston, W. J., Gill, P., & Burres, R. (2018). IoT adoption in agriculture: The role of trust, perceived value and risk. *Journal of Business and Industrial Marketing*, *33*(6), 804–821. doi:10.1108/JBIM-01-2018-0023

Kasalak, G., & Dağyar, M. (2020). The relationship between teacher self-efficacy and teacher job satisfaction: A meta-analysis of the teaching and learning international survey (TALIS). *Educational Sciences: Theory and Practice*, *20*(3), 16–33. doi:10.12738/jestp.2020.3.002

Kent, A., & Giles, R. (2017). Preservice teachers' technology self-efficacy. *Southeastern Regional Association of Teacher Educators, 29*. https://eric.ed.gov/?id=EJ1134392

Lai, C., Shum, M., & Tian, Y. (2016). Enhancing learners' self-directed use of technology for language learning: The effectiveness of an online training platform. *Computer Assisted Language Learning*, *29*(1), 40–60. doi:10.1080/09588221.2014.889714

Lluch, D., & Gros, B. (2018). *The relationship between age, technology acceptance model and grades obtained in the training of professional emergency services*. GenCat. https://interior.gencat.cat/ca/arees_dactuacio/bombers/coneix_els_bombers/que_fan_els_bombers/

Lunenburg, F. C. (2011). Self-efficacy in the workplace: Implications for motivation and performance. *International Journal of Management*. *Business Administration (London)*, *14*(1).

Manuti, A., Pastore, S., Scardigno, A. F., Giancaspro, M. L., & Morciano, D. (2015). Formal and informal learning in the workplace: A research review. *International Journal of Training and Development*, *19*(1), 1–17. doi:10.1111/ijtd.12044

Marikyan, D., & Papagiannidis, S. (2021). Technology acceptance model: A review. In S. Papagiannidis (Ed.), *TheoryHub Book*. http://open.ncl.ac.uk

Marton, F. (2009). Sameness and difference in transfer. *Journal of the Learning Sciences*, *15*(4), 499–535. doi:10.1207/s15327809jls1504_3

Mi-Young, K, & Hye-Kyung, L. (2019). A study on the influence factors of self-efficacy, job performance, and job satisfaction of university hospital nurses. *Journal of the Korean Applied Science and Technology*, *36*(3), 726–736. doi:10.12925/JKOCS.2019.36.3.726

Motowidlo, S. J., & Kell, H. (2013). *Job performance* (Vol. 12). Handbook of Psychology. Industrial and Organizational Psychology.

Nakamura, W. T., Marques, L. C., Rivero, L., de Oliveira, E. H. T., & Conte, T. (2019). Are scale-based techniques enough for learners to convey their UX when using a learning management system? *Revista Brasileira de Informática Na Educação*, *27*(01), 104. doi:10.5753/rbie.2019.27.01.104

Pajares, F. (1997). Current directions in self-efficacy research. *Advances in Motivation and Achievement: a Research Annual*, *10*, 1–49.

Pan, X. (2020). Technology acceptance, technological self-efficacy, and attitude toward technology-based self-directed learning: Learning motivation as a mediator. *Frontiers in Psychology*, *11*, 564294. doi:10.3389/fpsyg.2020.564294 PMID:33192838

Park, S. Y. (2009). An analysis of the technology acceptance model in understanding university students' behavioral intention to use e-learning. *Journal of Educational Technology & Society*, *12*(3), 150–162.

Quintana, R. M., Haley, S. R., Magyar, N., & Tan, Y. (2020). Integrating learner and user experience design: A bidirectional approach. In Learner and User Experience Research.

Rescue Act. (2011). Pub. L. No. 379/2011. https://www.finlex.fi/en/laki/kaannokset/2011/en20110379.pdf

Rivière, E., Jaffrelot, M., Jouquan, J., & Chiniara, G. (2019). Debriefing for the transfer of learning: The importance of context. *Academic Medicine*, *94*(6), 796–803. doi:10.1097/ACM.0000000000002612 PMID:30681450

Scherer, R., Siddiq, F., & Tondeur, J. (2019). The technology acceptance model (TAM): A meta-analytic structural equation modelling approach to explaining teachers' adoption of digital technology in education. *Computers & Education*, *128*, 13–35. doi:10.1016/j.compedu.2018.09.009

Schönfeld, P., Preusser, F., & Margraf, J. (2017). Costs and benefits of self-efficacy: Differences of the stress response and clinical implications. *Neuroscience and Biobehavioral Reviews*, *75*, 40–52. doi:10.1016/j.neubiorev.2017.01.031 PMID:28143761

Schønning, A., & Nordgreen, T. (2021). Predicting treatment outcomes in guided Internet-delivered therapy for anxiety disorders: The role of treatment self-efficacy. *Frontiers in Psychology*, *12*, 712421. doi:10.3389/fpsyg.2021.712421 PMID:34744872

Schunk, D. H., & Dibenedetto, M. K. (2016). *Handbook of motivation at school*. doi:10.4324/9781315773384.ch3

Stajkovic, A. D., & Luthans, F. (1998). Self-efficacy and work-related performance: A meta-analysis. *Psychological Bulletin*, *124*(2), 240–261. doi:10.1037/0033-2909.124.2.240

Story, D. A., & Tait, A. R. (2019). Survey Research. *Anesthesiology*, *130*(2), 192–202. doi:10.1097/ALN.0000000000002436 PMID:30688782

Sundar, S. S., & Marathe, S. S. (2010). Personalization versus customization: The importance of agency, privacy, and power usage. *Human Communication Research*, *36*(3), 298–322. Advance online publication. doi:10.1111/j.1468-2958.2010.01377.x

Thalmann, S., Ley, T., Maier, R., Treasure-Jones, T., Sarigianni, C., & Manhart, M. (2018). Evaluation at scale: An approach to evaluate technology for informal workplace learning across contexts. *International Journal of Technology Enhanced Learning*, *10*(4), 289–308. doi:10.1504/IJTEL.2018.095124

Tofade, T., Elsner, J., & Haines, S. T. (2013). *Best practice strategies for effective use of questions as a teaching tool*. AJPE. http://www.ajpe.org

Tynjälä, P. (2008). Perspectives into learning at the workplace. *Educational Research Review*, *3*(2), 130–154. doi:10.1016/j.edurev.2007.12.001

Venkatesh, V., & Davis, F. D. (2000). Theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, *46*(2), 186–204. doi:10.1287/mnsc.46.2.186.11926

Venkatesh, V., Morris, M., Davis, G., & Davis, F. (2003). User acceptance of information technology: Toward a unified view. *Management Information Systems Quarterly*, *27*(3), 425–478. doi:10.2307/30036540

Vogelsang, K., Steinhüser, M., & Hoppe, U. (2013). *A qualitative approach to examine technology acceptance*. ICIS.

Wang, S., Wang, J., Li, J., Wang, J., & Liang, L. (2018). Policy implications for promoting the adoption of electric vehicles: Do consumer's knowledge, perceived risk and financial incentive policy matter? *Transportation Research Part A, Policy and Practice*, *117*, 58–69. doi:10.1016/j.tra.2018.08.014

Weidinger, J., Schlauderer, S., & Overhage, S. (2021). Information technology to the rescue? Explaining the acceptance of emergency response information systems by firefighters. *IEEE Transactions on Engineering Management,* (pp. 1 –15). IEEE. 10.1109/TEM.2020.3044720

Young Hwang, J., Young Kim, K., & Hyun Lee, K. (2009). Factors that influence the acceptance of telemetry by emergency medical technicians in ambulances: An application of the extended technology acceptance model. *Telemedicine Journal and e-Health*, *20*(12), 1127–1134. doi:10.1089/tmj.2013.0345 PMID:25531202

## APPENDIX

### User Experience Questionnaire

1. How do you feel after using the tool?
2. How was your experience?
3. What did you miss?
4. What was motivating?
5. What was demotivating?
6. How was it to use BUST without prior experience?
7. What would help users better learn BUST?
8. How was the user interface (i.e., buttons, symbols, menus, icons, text sizes)?
9. Was anything surprising?
10. Did something not perform as expected? Explain.
11. How difficult was it to learn to use BUST?

*Filip Sever is a project manager at Kajaani University of Applied Sciences, Finland. He has worked on projects in education, education export, tourism innovation, and most recently in civil security. Filip holds an MA, Education from the Learning, Education and Technology programme at the University of Oulu.*